TECHNICAL MEMORANDUM

NO. 4

PERFORMANCE AND VALIDATION PLAN

FOR CRUP CONDITION ASSESSMENT PROGRAM

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREIGN AGRICULTURAL SERVICE

NASA-JSC

UNITED STATES DEPARTMENT OF AGRICULTURE

FOREIGN AGRICULTURAL SERVICE

PERFORMANCE AND VALIDATION PLAN FOR CROP CONDITION ASSESSMENT PROGRAM	FIRST ISSUE

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1. REASON FOR ISSUANCE

To document steps taken to validate Crop Condition Assessment System hardware and software from initial delivery to the current time and to provide basic guidelines for future validation activities and routine evaluation of output products.

2. COVERAGE

This plan applies to all Crop Condition Assessment System hardware and software modifications or enhancements and all resulting output products routinely generated in support of documented mission statements.

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PART 1.0 BASIC PROVISIONS

1.1 PURPOSE

- To document steps taken to validate Crop Condition Assessment System (CCAS) hardware and software from initial delivery to current time.
- To define activities necessary to validate system performance in terms of clustering and classification functions.
- To define general guidelines and procedures to be followed when additional capabilities are implemented.
- To provide basic guidelines for routine evaluation of output products generated to satisfy user requirements within the confines of documented CCA mission statements.

1.2 BACKGROUND

Hardware components and specified software modules were procured by USDA. The CCAS was designated as a research and development (R&D) system.

The prime function of the CCA program is crop condition assessment, not crop inventory. This primary function will be reflected in output products to be routinely evaluated.

A selected group of USDA analysts received preliminary training on the I-100 system located in Building 17, Johnson Space Center. Initial analyst training regarding use of image analysis software modules and computer operator system training was conducted by Ford Aerospace and Communications Corporation (FACC).

1.3 PARTICIPANTS

In addition to USDA personnel, appropriate contractor personnel, specifically representatives of the Ford Aerospace and Communications Corporation (FACC) and the Lockheed Electronics Corporation (LEC) and NASA personnel (EOD/ERPO) will be invited to participate in system testing and evaluation activities conducted at the sample segment level and above. Pixel level testing and evaluation will be a joint CCA/FACC activity.

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PART 2.0 ADP SYSTEM VALIDATION

2.1 OVERVIEW

The CCAS has been subjected to a series of validation procedures to verify ADP consistency. This validation process will continue and be expanded as new capabilities are added. The primary validation testing is listed below.

2.2 INTERNAL CONTRACTOR TESTING

Prior to the award for image analysis equipment, FACC had tested the nucleus of software that would be the basis of image processing software for the CCAS. This testing was undertaken based on a plan, Detailed Test Procedures Specification for the Integrated Multivariate Data Analysis and Classification System (IMDACS), dated March 18, 1977. Testing was concluded in May and the image processing software was internally accepted by FACC.

2.3 CCAS ACCEPTANCE TEST PLAN AND RESULTS

After award of the image analysis equipment contract to FACC, USDA and FACC personnel developed a system test approach which relied on two methods of validation.

2.3.1 System Executive Software. The system executive software, such as the operating system and compilers, was to be tested by actual programmer use prior to acceptance of the system. USDA analysts/programmers began using the system for applications two months prior to system acceptance. No significant deficiencies were detected.

2.3.2 Image Processing Software. Image processing software was also evaluated in accordance with a specific plan, Acceptance Test Plan for the Single Thread System, dated July 15, 1977. This plan led to a detailed procedure, Test Procedures Specification, USDA ATS Integrated Multivariate Data Analysis and Classification System (IMDACS), dated October 10, 1977. IMDACS is a proprietary image processing package of FACC. Source code, while available to USDA, is not releasable to third parties. Therefore, the test plan stressed step-by-step processing of images and output results so that these could be reviewed by third parties assisting USDA in the evaluation.

Testing was completed on October 4, 1977. Thirty-seven (37) discrepancies were documented by USDA and were transmitted to FACC for resolution. The one unresolved discrepancy was that clustering/classification validation was a continuing process, that this validation must always - because of differences in system architecture - contend with results differences (CCAS and ERIPS),

However, the immediate needs of USDA (i.e., crop analyst training and application programming) were served by the CCAS as then configured. Accordingly, the 30-day acceptance period began on October 21, 1977.

2.3.3 Data Base Management System (DBMS) Software. The DBMS was accepted on October 13, 1977, using the IDMS (DBMS-11) Acceptance Test Procedure. No discrepancies were noted during the acceptance test and no deficiencies have been discovered during subsequent usage.

2.4 AGENA BUILDING ACCEPTANCE TEST

When the CCAS equipment was moved to the Agena Building, the system was subjected to the same acceptance test procedures referenced in Section 2.3. No new discrepancies were noted.

2.5 FUTURE TESTING

Future testing is required for two FACC deliverables.

2.5.1 Multistation IMDACS Software. Although testing of this software package is incomplete, one serious discrepancy has been noted. The discrepancy is that one analyst station can gain control of another station's images. FACC reported that the problem had been resolved, and a plan for testing the resolution of this discrepancy was available on July 21, 1978. Testing was initiated on August 9, 1978.

2.5.2 Query/Report Writer. A briefing regarding the capabilities of this software package was presented to CCA programmers and crop analysts by FACC on July 31, 1978. A test plan was prepared by FACC, and testing was initiated on August 11, 1978.

PART 3.0 ANALYSIS CAPABILITIES AND PROGRAMS

3.1 OVERVIEW

Existing and planned capabilities of the CCAS are presented below in terms of computer software packages available to support specific analysts and administrative functions. Capabilities are stratified in terms of those that are currently operational, those currently in development and testing phases, and planned enhancements.

3.2 OPERATIONAL

Capabilities listed below are considered operational, i.e., initial testing has been completed, and software is available for routine use. Final documentation of test procedures and test results is in progress.

3.2.1 Data Conversion and Load Programs

3.2.1.1 Sample segment batch load programs. Loads sample segments to disk for use by IMDACS.

3.2.1.2 Meteorological data conversion. Translates data received from Building 17, JSC, via magnetic tape for EBCDIC to ASCII.

3.2.1.3 Tape conversion. Generalized EBCDIC to ASCII conversion program.

3.2.1.4 Grid generation program. Product IJ grids for the gridded data base.

3.2.1.5 Date base. Data base is completely structured and is loaded to country/crop levels.

3.2.2 Image Analysis/Analyst Aids

3.2.2.1 Vegetation index computation program. Computes vegetation indexes.

3.2.2.2 General purpose plot program locates and plots the following items.

3.2.2.2.1 Vegetative index numbers for a sample segment.

3.2.2.2.2 Soil moisture budget output from either gridded data or data spread based on point observations to either grids or sample segments.

3.2.2.2.3 Crop calendar output from either gridded data or·data spread based on point observations to either grids or sample segments.

3.2.2.2.4 Sample segment location.

3.2.2.2.5 Sample segments acquired on a specified Julian data or for fixed periods (e.g., 18-day intervals).

3.2.2.3 Image masking program. Image masks for selected acquisitions over the same geographic area, on which vegetative indexes can be calculated.

3.2.2.4 Wheat separability system. A series of computer programs to aid in wheat separability analysis. Fifteen software modules were obtained from LEC to produce specified data plots (e.g., green number).

3.2.2.5 Graphic terminal programs. A series of programs to demonstrate graphic terminal capabilities in terms of plotting functions, soil information retrieval and meteorological alarm displays.

3.2.3 <u>Statistical Techniques</u>

3.2.3.1 Discrimination analysis statistical program. Discriminates within a population based on attributes. Has been used primarily as an aid in discriminating between wheat and small grains.

3.2.3.2 Correlation/multiple regression. Primary use has been correlation of vegetation indexes and wheat yield.

3.2.3.3 Analysis of variance. Used primarily for analysis of vegetation indexes versus area.

3.2.4 <u>Administrative Support</u>

3.2.4.1 Cost and budget system. Used extensively to develop budget alternatives for USDA. Consists of fourteen (14) subprograms under one executive program.

3.2.4.2 Tape inventory program. Used to maintain the inventory of magnetic tapes.

3.3 DEVELOPMENT (TESTING)

Software packages listed below are in the developmental stage and will be ready for testing in the near future. Appropriate test procedures will be developed and applied before individual software packages are made available for routine analytical use.

3.3.1 Data Base. Ten data load programs and nine supporting data conversion programs.

3.3.2 Yield Models. CCEA I models for the U.S. and the U.S.S.R. and Feyerherm (KSU) model.

3.3.3 Meteorological Alarm System. A series of programs to identify unusual meteorological conditions and alert the analyst.

3.3.4 P-1 Integration. Integration of P-1 into IMDACS will be a joint undertaking of USDA, FACC and LEC.

3.4 PLANNED ENHANCEMENTS

A number of anticipated image processing software enhancements are summarized in this section. Order of listing does not necessarily imply implementation priority.

3.4.1 IMDACS-Specific Enhancements.

3.4.1.1 Replace the present IMDACS field definition module with software that will allow up to 29 field vertices (current limit is 10).

3.4.1.2 Provide analyst with the option of specifying signature generation parameters for each field one time and default to these parameters for all fields if respecification is deemed unnecessary.

3.4.1.3 Replace X, Y values on CRT with line and pixel coordinates for selected pixels and points (using cursor).

3.4.1.4 Display a "class summary file" prior to class display parameter requests.

3.4.1.5 Default parameters for iterative and adaptive clustering that are compatible with ERIPS.

3.4.1.6 Provide a capability to display histograms on the VT-55.

3.4.2 Other Enhancements.

3.4.2.1 Provide for identifying a bounded or point field with the cursor.

3.4.2.2 Provide a capability to enclose a group of dots being displayed in a scatter plot. All dots enclosed in this field are to be presented to the analyst for labeling in the same manner as the group labeling function in P-1.

3.4.2.3 Generalize the dot labeling capability to non-grid pixels and fields.

3.4.2.4 Allow relabeling of fields without deleting them.

3.4.2.5 Compute the vegetation indexes of fields for inclusion in the scatter plot.

3.4.2.6 Develop an improved status and tracking system using the CCAS DBMS.

PART 4.0 IMAGE PROCESSING, TESTING AND VALIDATION.

4.1 OVERVIEW

The purpose of this testing/validation is to verify that hardware and software components perform specified design functions correctly. This is not an accuracy assessment evaluation of analyst/machine performance.

4.2 SCOPE OF TESTING

Clustering and classification are the primary elements to be tested against documented design specifications. Validation of segment-level results will be a joint effort of USDA, NASA, FACC and LEC. Pixel-level tests will be performed internally by USDA and FACC. Continuing validation of IMDACS results with results obtained from ERIPS is anticipated.

4.3 RESPONSIBILITIES

4.3.1 USDA Crop Condition Assessment System (CCAS)

4.3.1.1 Select candidate segments for test.

4.3.1.2 In conjunction with FACC, define the ERIPS/IMDACS clustering and classification parameters to be used.

4.3.1.3 Define the test segment runs to be made on ERIPS.

4.3.1.4 Deliver and pick up data from Buildings 17 and 30, JSC.

4.3.1.5 Perform the lead role in analysis of results; required support to be provided by FACC.

4.3.1.6 Establish schedule dates for test completion and for correction action by FACC as required.

4.3.1.7 Overall management of test and documentation of task procedures and results to USDA accepted standard.

4.3.1.8 Provide status reports as agreed to by USDA and NASA management.

4.3.2 NASA, EARTH OBSERVATIONS DIVISION, JSC

4.3.2.1 Provide current documentation for LACIE operational iterative clustering options used on all data sets in the 1976-77 crop year.

4.3.2.2 Provide one test image used in ERIPS validation.

4.3.2.3 Provide Landsat data for selected segments; images should be unloaded to tape and all acquisitions for each segment merged. It is desirable to have all images unloaded and merged on one tape.

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4.3.2.4 Perform no more than 34 computer runs on selected inhouse data. Diagnostic listings from clustering and classification are desirable <u>if</u> no resource impact is incurred in their production.

4.3.2.5 Notify the CCAS task leader when data are ready.

4.3.2.6 Provide two man days of consultation on documentation and clarification of ERIPS results.

4.3.3 <u>Ford Aerospace and Communications Corporation</u>

4.3.3.1 Prepare detailed test plan, obtain USDA approval of test plan, and perform all IMDACS test processing with the USDA task leader as a full-time observer and test director.

4.3.3.2 Thoroughly document analysis performed leading to test results delivered to USDA.

4.3.3.3 Assist in defining ERIPS runs (especially option selections).

4.3.3.4 Assist USDA in performing comparability analysis and in documenting results.

4.4 MEASURES OF PERFORMANCE

4.4.1 Segment-level results for both clustering and classification must be comparable to the significant digit (whole percent). Test success or failure <u>will not</u> be judged on intermediate results (i.e., results below the segment level).

4.4.2 Availability/non-availability of identical clustering options in ERIPS and IMDACS <u>will not</u> be used as a measure of success/failure in this test.

4.4.3 Repeatability of procedures to achieve comparable results is critical.

4.5 SCHEDULES

All schedules will be predicated on established USDA/FACC priorities and negotiations under the existing contract structure.

PART 5.0 ACCURACY ASSESSMENT

5.1 LEVEL OF TESTING

5.1.1 First Order Tests. To evaluate methods, procedures and algorithms implemented from LACIE and/or developed by CCA personnel against predefined end-user information requirements in terms of accuracy, timeliness and continuity of data.

5.1.2 Second Order Test. To determine those system components (methods, procedures, algorithms) that do not meet, or that contribute to the inability of the CCAS to meet predefined information requirements.

5.1.3 Third Order Test. To compare CCAS results, from methods, procedures and algorithms transferred from the LACIE for consistency with LACIE results using the same procedures and to document that LACIE transferred technology yields LACIE expected results.

5.2 ELEMENTS TO BE TESTED

5.2.1 Comparison of LACIE and CCAS Segment Level Estimation. The objective of this test is to compare the small grains proportion estimate produced by the CCAS with that produced by LACIE. All blind sites in North Dakota and Montana for the 1978 crop year will be used for this test. The proportional estimates from both systems on identical data sets will be compared to actual ground truth segments. Evaluation of the absolute error in the small grains proportion estimate for both the CCAS and LACIE will be reported. If any significant differences between the two systems exist, when the segment level proportion estimates are made, these differences will be reported.

5.2.2 Comparison of CCA procedures. The objective of this test is to compare the accuracy of the analyst selected fields procedure with the accuracy of the P-1 procedure.

Thirty Phase III blind sites from North Dakota and Montana will be selected. They should exhibit the range of characteristics expected in the spring wheat area of the northern Great Plains. These sites will be grouped into five data sets of six types reflecting levels of various factors hypothesized to affect accuracy. Examples of such factors are the actual wheat or small grains proportion, acreage, field size, and the presence of confusion crops. The five segments for each type should be similar enough so that there is not an *a priori* reason to expect one to be easier or more difficult to analyze than others of that type.

For each segment processed, the analysts shall in a single session choose and label all analyst selected fields and dots for P-1. The order of processing will be specified prior to testing. Once the labels are selected, procedures will be applied to the segment to give two small grains proportion estimates.

The only variable to be checked is the absolute error in the small grains proportion estimate as compared to available ground truth. Inferential tests to identify significant differences between procedures will be made; specifically, analysis of variance techniques will be applied to data obtained from the experiment.

5.2.3 Analysts Labeling Accuracy. The objective of this test is to evaluate the learning curve for experienced and inexperienced CCA analysts as the crop year progresses in terms of labeling accuracies and variabilities. Each analyst will be required to process three blind sites from Phase III for evaluation prior to processing any data for the 1978 crop year. After the initial data set is evaluated, each analyst will process additional data sets through the growing season as part of normal operations for evaluation. Appropriate statistical techniques will be used to test for significant differences between analysts.

5.2.4 Yield Models. Two yield models (CCEA I and Feyerherm-KSU) developed and run in LACIE are to be implemented and tested.

5.2.4.1 CCEA I Models. The CCEA I regression models using monthly average temperatures and monthly total precipitation will be tested. Phase III operational model results will be compared with results obtained from Phase III models implemented by the CCAS unit using identical input values. Transition Year operational model results (models implemented April 1, 1978, by LACIE for the U.S. Great Plains) will be compared monthly with results of the CCA-implemented, updated version of the CCEA I models using current year inputs.

5.2.4.2 Feyerherm (KSU) Model. The Feyerherm model, as implemented in the CCAS, will be validated by comparing Phase III LACIE output for North Dakota and Tselinograd to CCA-implemented model results using identical inputs to be furnished by EOD. The winter wheat model will be implemented and tested upon receipt of new version and test inputs from EOD.

5.2.4.3 Output Products. CCEA I yield models will be operated over the U.S.S.R. for both winter and spring wheat during the 1977-78 crop season. Yield estimates will be generated monthly beginning in mid-April (weather data through March) for winter wheat and mid-May (weather data through April) for spring wheat. Information provided for each crop region will include the following items:

- Current month yield prediction
- Past month(s) yield prediction
- Yield change from previous month

- o Specific weather phenomenona causing change
- o Past month(s) weather (temeprature and precipitation deviation from normal)
- o Cumulative seasonal impact of weather with breakdown (temperature and precipitation) on yield by month
- o Comparison of current month yield with one year ago
- o Comparison of current month yield with trend (percent deviation)

5.2.5 Crop Calendar. The wheat crop calendar, as developed by Robertson and implemented by Feyerherm as an integral part of his yield model, will be tested. Daily input data derived by LEC as input into the KSU yield model tests for the 1975 and 1976 crop years in Kansas and North Dakota will be run through the CCA-implemented crop calendar. CCA-generated daily growth stage results will be compared with LACIE-generated results. This test will include validation of the spring wheat starter model.

5.2.6 Crop Condition Assessment. The objective is to test and evaluate the effectiveness of selected procedures in detecting the existence of conditions that may affect crop area, yield and/or production and in quantifying the impact of the identified conditions in terms of direction and estimated magnitude.

5.2.6.1 Climatic Alarm System. This system, as currently structured, utilizes automated meteorological parameters to flag adverse climatic conditions that affect the growth, development and ultimate condition of the crop throughout the growing season. This capability provides a means of monitoring current year conditions and assessing the year-to-year variability in meteorological parameters that may have an adverse effect on crop area, yield and/or production.

A series of reports will be generated for selected areas of the U.S. and the U.S.S.R. to alert analysts/users regarding the existence and extent of specified phenomena. The first report will indicate that a significant departure from normal climatic conditions has occurred or that a specified combination of conditions has been detected. A second report, derived from monitoring an event over time, will confirm the existence of a problem and will provide the areal extent via an isoline map based on satellite data. A third report will qualitatively assess the impact of the event and will portray supportive data in the form of isoline maps for the following elements: (1) soil moisture, (2) precipitation, (3) temperature, and (4) overlay of vegetation index(es).

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5.2.6.2 Vegetation Indexes. The objective is to test and evaluate selected methods for computing vegetative index numbers (VIN). An intermediate step will be to correlate vegetative index numbers at the sample segment level with crop growth stages, soil moisture, crop yield and crop biomass.

Stress line geographic plots will be produced to reflect the current vegetative index for a given area. These plots will be overlaid on a map of the related area. The VIN and associated plots will provide the user an indication of vegetative condition and a correlation with soil moisture which can be related to growth stages of crops in the area being analyzed. VIN plots will be generated at spring greenup and will continue through harvest for U.S.S.R. spring wheat areas and for selected areas in the U.S.

5.2.7 Data Base. To test and evaluate the accuracy of the climate, soils, ag/non-ag, and historical data to be loaded at the 25x25 nm grid cell level, and to each quadrant where possible.

5.2.8 Agrophysical Unit (APU) Maps. These maps consist of delineations of land areas of relatively homogeneous agricultural use, density and potential in relation to soils, climate, topography, and agronomic practices.

The unit is commonly referred to as an APU. This type of regionalization is highly supportive of crop condition analysis as related to the total range of existing circumstances that impact crop production. This year's maps will cover selected areas of the U.S.S.R. and U.S.

5.3 DATA REQUIREMENTS

The evaluation functions will require supporting data for North Dakota, Montana and one APU in the U.S.S.R. from the following categories:

- ITS
- Blind Sites
- Historical estimates
- Current estimates and periodical reports
- Historical and current MSS data
- Historic and current meteorological summaries and climate crop assessment
- Segment, APU, political overlays
- Soils maps and related classification ag/non-ag overlays

In addition to the data specified above, data from other areas will be required to support training and procedures development tasks.

5.4 EVALUATION REPORTS

Each report will be a stand-alone document following the outline listed below:

- Evaluation Report Number
  - Task description
  - Task requirements
  - Task summary and objectives
  - Statistical comparisons
  - Statistical test
  - Task evaluation results
  - Review and recommendations

5.5 MANAGEMENT

5.5.1 Task Manager. This responsibility will be within the CCA unit. It is the task manager's responsibility to assign task monitors, recommend task leaders and candidate task members. Along with Task Review Team, accept and/or recommend additional action needed for each task upon completion of review.

5.5.2 Task Monitor. This responsibility will be within the CCA unit. It is the responsibility of the Task Monitor to maintain and report on resources and schedule changes and to work interfaces within the CCA unit and other LACIE organizations, assist task leader as necessary in performance of evaluations.

5.5.3 Task Leader. This responsibility will be assigned to a professional from any agency participating in the experiment. It is the Task Leader's responsibility to manage the technical activity of the Task Team in an efficient and orderly evaluation.

5.5.4 Task Team. Each team member will be selected based upon needed skills and project experience required to properly complete each task evaluation, from various participating agencies.

5.6 INTERFACES

Most interfaces will occur in the normal day-to-day data flow between NASA, NOAA and USDA. Additional interface requirements will be developed for specific tasks as the need arises. Initially, the major impact will be within the CCA unit in terms of task development and evaluation.

5.6.1 External Interfaces. A close working relationship with LACIE Accuracy Assessment personnel (civil servants and support contractors) is necessary to optimize use of available resources. Interfaces with other EOD and ERPO personnel will be on an as needed basis.

5.6.2 Internal Interfaces. Regular interaction with CCA personnel in the ADP support group and the analyst unit will be necessary to perform routine product evaluations and system performance tests.

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EXHIBIT 1: REFERENCES

1. Detailed Test Procedures Specification for the Integrated Multivariate Data Analysis and Classification System (IMDACS), dated March 18, 1977.

2. Acceptance Test Plan for the Single Thread System, dated July 15, 1977.

3. Test Procedures Specification, USDA ATS Integrated Multivariate Data Analysis and Classification System (IMDACS), dated October 10, 1977.

4. IDMS (DBMS-11) Acceptance Test Procedure, dated October 13, 1977.

5. Memorandum LACIE-78-538, dated April 21, 1978, subject "ATS Data Requirements for 1978."

6. Memorandum LACIE-78-196, dated July 17, 1978, subject "Test and Evaluation of the USDA-IMDACS Clustering and Classification System."

7. Memorandum LACIE-78-625, dated July 18, 1978, subject "ERIPS/IMDACS Test-Image Unload and Merge."

8. NASA Memorandum SF-12, dated July 13, 1978, subject "USDA Requested Actions Related to ATS Systems Verification."

9. NASA Memorandum SF-12, dated July 19, 1978, subject "ERIPS Iterative Clustering Documentation."

FIGURE 3-2 OBSERVED AND ESTIMATED YIELDS
vs. LAIMSM3 AT HEADING, FIELDS GREATER THAN 30 PIXELS